

How sensor technology is changing the world of robotics

Advances in sensor technologies will profoundly shape the robots of tomorrow

HBK's advanced sensor solutions ensure precise adaptation, seamless integration, and reliable performance in the rapidly evolving field of modern robotics, where innovation and precision are paramount.

Overcoming Challenges with Advanced Sensor Solutions

The rapid growth of the robotics industry is driving the adoption of robots in a number of sectors. However, this expansion comes with significant challenges. HBM, leader in this field offers testing, measurement, and sensor integration solutions, helping engineers bring visionary concepts to life. With cutting-edge tools and sensors, they optimize the performance of robotic systems through real-time data-driven testing and decision-making

Automation and digitisation challenges in robotics

Of all the recent developments in modern industry today, none have been more notable than the surge of robotics.

The use of robots and robotics has rapidly spread into multiple industries, with the robotics technology industry estimated to be worth US\$283 billion by 2032. This expansion is expected to increase even further, according to Precedence Research, as the market is predicted to grow almost 15% a year between 2023 and 2032.

As a result, new market trends are emerging, including the rise of autonomous robots and the integration of robotics into traditionally manual domains such as agriculture and transportation.

However, the robotics industry still faces several major challenges. Robots must quickly adapt to dynamic environments, seamlessly integrate multiple sensors, and reliably recognise and classify various objects.

One of the major areas affected is industrial automation, which seeks to enhance manufacturing, material handling, and quality control through automated processes and machinery. Despite its importance, industrial automation presents significant challenges such as high implementation costs and complex integration requirements.

Digitisation also introduces additional challenges. Integrating with cloud computing, ensuring regulatory compliance, and managing cybersecurity risks are substantial obstacles. Smooth and secure integration of digital systems is crucial for data protection and regulatory adherence. In addition, digitisation also involves handling increasing volumes of data and ensuring effective interconnectivity between various platforms and devices.

Advanced sensor technologies play a crucial role in addressing these challenges. They enable robots to perceive, interpret, and respond to their environment with precision and efficiency while providing reliable information to human operators. These technologies allow robots to operate more autonomously and adapt to the evolving needs of different sectors.

How HBM drives innovation in robotics with cutting-edge sensor solutions

In the rapidly evolving field of modern robotics, where innovation and precision are paramount, HBM stands out as the go-to choice for sensor testing, measurement, and integration. The merger of HBM, a leader in measurement, testing, and analysis, and Brüel & Kjær, a global pioneer in sound and vibration measurement, has created HBM, a powerhouse combining rich legacies of excellence and ingenuity.

Over the past ten years, between HBM and Brüel & Kjær collectively, we have made several acquisitions to broaden our expertise, including LDS Test and Measurement, nCode, SoMat, Sound Answers, FiberSensing, and ReliaSoft.

However, our journey is a continuous one and the ever-growing HBM constellation reflects our ongoing commitment to innovation, the latest technology, and new opportunities as we tap into the potential of combined knowledge and insight within three physical domains – mechanical, sound and vibration, and electrical.

Our recent acquisition of MicroStrain, a specialist in precision inertial and wireless sensing systems, further diversifies HBM's offerings, providing tailored solutions for specific robotics requirements. This collaboration with MicroStrain reinforces our mission to create sustainable solutions for a cleaner, healthier, and more productive world.

Engineers tasked with design, testing, and measurement face intricate challenges in bringing visionary concepts to fruition. We understand these challenges and are committed to accelerating innovation, streamlining processes, and simplifying workflows.

Through cutting-edge sensors and tools, HBK bridges the gap between concept and reality, enabling seamless testing and data-driven decision-making while delivering critical real-time feedback and control data, thereby optimising robotic system performance.

We go beyond merely supplying products; we forge strong partnerships with our clients in the robotics industry. Our reputation as a trusted partner is built on a history of successful collaborations and our ability to offer industry-leading technologies and solutions.

HBK is the clear choice for those seeking innovative, top-tier sensor solutions for their robotics applications. By combining technical expertise with an unwavering commitment to innovation, we are equipped to meet the future challenges of robotics and drive advancements in this dynamic field.

“HBK'S TECHNICAL EXPERTISE AND COMMITMENT TO INNOVATION DRIVES FUTURE ADVANCEMENTS IN ROBOTICS

About

- 35,000 Customers Served
- 300+ Employees Working in R&D
- Innovation for more than 80 Years

Advanced Sensor Solutions for In-Robotics Applications

HBK leads with a comprehensive range of cutting-edge sensor solutions tailored to meet robotics' exacting demands. From enhancing efficiency to advancing autonomous capabilities, our sensors empower engineers and designers to achieve precise objectives with confidence and innovation.

HBK's robotic sensor solutions

HBK offers a comprehensive range of sensor solutions designed to meet the stringent requirements of robotics. Whether enhancing efficiency or pushing the boundaries of autonomous systems, our sensor solutions empower engineers and designers to achieve their objectives with confidence.

As a leader in this field, HBK provides strain gauges for structural durability testing and stress analysis, ensuring product safety and performance. Our solutions also include sensors based on strain gauges for measuring force, torque, and load, as well as inertial and wireless sensors for seamless integration into robotic systems.

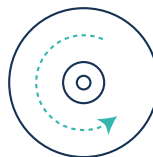
Our sensors enable robots to detect and navigate obstacles, collect real-time feedback, and position themselves accurately. The design focuses on meeting technological, weight, and space constraints, providing the reliability and precision required for sophisticated robotic capabilities.

HBK offers a variety of options to meet diverse needs:

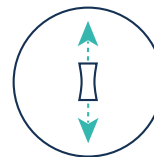
- **Off-the-shelf sensors:** Ideal for standardised testing, with numerous standard references available for swift and seamless integration into existing systems
- **Customisable sensor solutions:** Adaptable standard sensors tailored to specific application requirements
- **Custom sensor designs:** Fully custom solutions meticulously crafted for unique space or size constraints, ensuring optimal performance in demanding environments

Our world-class production capabilities further enhance our services, with ISO-certified facilities in Marlborough, MA, USA; Darmstadt, Germany; and Suzhou, China, ensuring high-volume production of sensor assemblies to meet global demand. Lean manufacturing principles and advanced automation technologies maintain efficiency and precision across all facilities, demonstrating our commitment to delivering high-quality sensor solutions on a large scale and meeting the evolving needs of customers worldwide.

“**SENSOR
TECHNOLOGIES FOR
TESTING AND
SEAMLESSLY
INTEGRATING INTO
ROBOTIC SYSTEMS**”



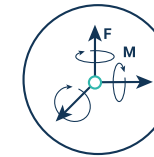
Torque



Strain



Load / Force



Multiaxis



Acceleration



Wireless

Robotic sensor applications

For OEM robot designers, seamless sensor integration is crucial for ensuring the optimal performance of their robots. Sensors gather data on all interactions and provide real-time feedback to the control program.

HBK caters to the needs of OEM robot designers by offering measurement solutions tailored to the operation of robotic systems, engineered as comprehensive measurement solutions that integrate measurement technology, sensor body, cables, and electronics into a cohesive unit. Drawing on our expertise, our engineering teams can devise sensor solutions that work to even the most intricate specifications.

Additionally, with the acquisition of MicroStrain, we have broadened our portfolio of robotic solutions, providing inertial measurement units (IMUs) and complete inertial navigation systems (GNSS/INS) to meet localisation and navigation requirements.

Navigation and localisation

Robots rely on a suite of sophisticated sensors to navigate autonomously and precisely determine their location. GNSS/INS sensors – similar to GPS systems – allow robots to reliably map their surroundings and follow predetermined routes.

In agriculture, these sensors help robots traverse expansive fields, while in warehouses, they ensure optimal routing for mobile robots among highly stacked shelves.

Manipulation and grasping

Precision in object manipulation is a critical skill for many industrial robots and cobots. Integrated force sensors allow robots to grasp and manipulate items with millimetre-level accuracy, minimising the risk of damaging a product.

In industrial settings, these sensors ensure efficient and safe manufacturing processes. By measuring torque and forces on joints, or directly on flexsplines, sensors enhance safety and transform the system into an intelligent one with continuous feedback. Integrated multi-axis sensor solutions enable better manipulation to ensure that the robot applies the necessary force, no matter how great or small, to the task at hand.

Autonomous operation and control

The autonomy of robots relies on an intelligent combination of sensors, such as GNSS/INS sensors, force sensors, and pressure sensors. These advanced technologies enable robots to make real-time decisions and respond to changes in their environment, ensuring safe and efficient operations.

In the medical field, for instance, these sensors ensure the precision of robot-assisted surgical procedures.



Robotic sensor submarkets: Exploring the diverse landscape of robotics technology

From manufacturing to healthcare, industrial and service robots transform sectors with advanced sensors and automation, driving innovation and facing new challenges. Robotics technology is divided into two main categories: industrial robots and service robots.

Industrial robots

Industrial robots are utilised in manufacturing to perform repetitive tasks. They can be stationary or capable of automated, programmable movements. Common applications include material handling, assembly, disassembly, soldering, and welding, predominantly in the automotive, manufacturing, and logistics sectors.

Industrial robots can be classified into six main types: SCARA, articulated, collaborative, Cartesian, parallel, and others. The collaborative and articulated robots are the most significant contributors to the market.

Service robots

Service robots perform tasks that benefit the wellbeing of humans and equipment, excluding manufacturing operations. While there are some similarities to industrial robots, service robots are primarily designed for various applications such as healthcare, hospitality, and cleaning.

Technological advances and challenges

The robotics industry encompasses various submarkets, including collaborative, medical, and agricultural robots, each presenting unique challenges. Recent technological advances, such as enhanced sensors and computer vision, have significantly improved the capabilities of collaborative robots.

However, these advancements also introduce new challenges, such as miniaturisation for medical robots and autonomous operation for agricultural robots. Sensor technologies developed for collaborative robots can be adapted for use in other sectors, fostering cross-industry innovations.

In the following sections, we will provide specific examples of different applications within each submarket.

“RECENT TECH
ADVANCES BRING
NEW CHALLENGES
SUCH AS
MINIATURISATION
AND AUTONOMOUS
OPERATIONS

Traditional industrial robots

Conventional industrial robots are indispensable work-horses in modern manufacturing, performing repetitive tasks with unmatched precision and efficiency.

These machines, either stationary or equipped with automated programmable movements, are essential across sectors like automotive, manufacturing, and logistics. Typical applications include assembling electronic components, palletising, material handling, quality control and inspection, machining, as well as product sorting and packaging – optimising production processes.

Industrial robots can be categorised into six main types: SCARA, articulated, collaborative, Cartesian, parallel, and others. However, industrial robot designers face unique hurdles due to increasing demands for higher precision, reliability, and efficiency in increasingly complex and automated production environments.

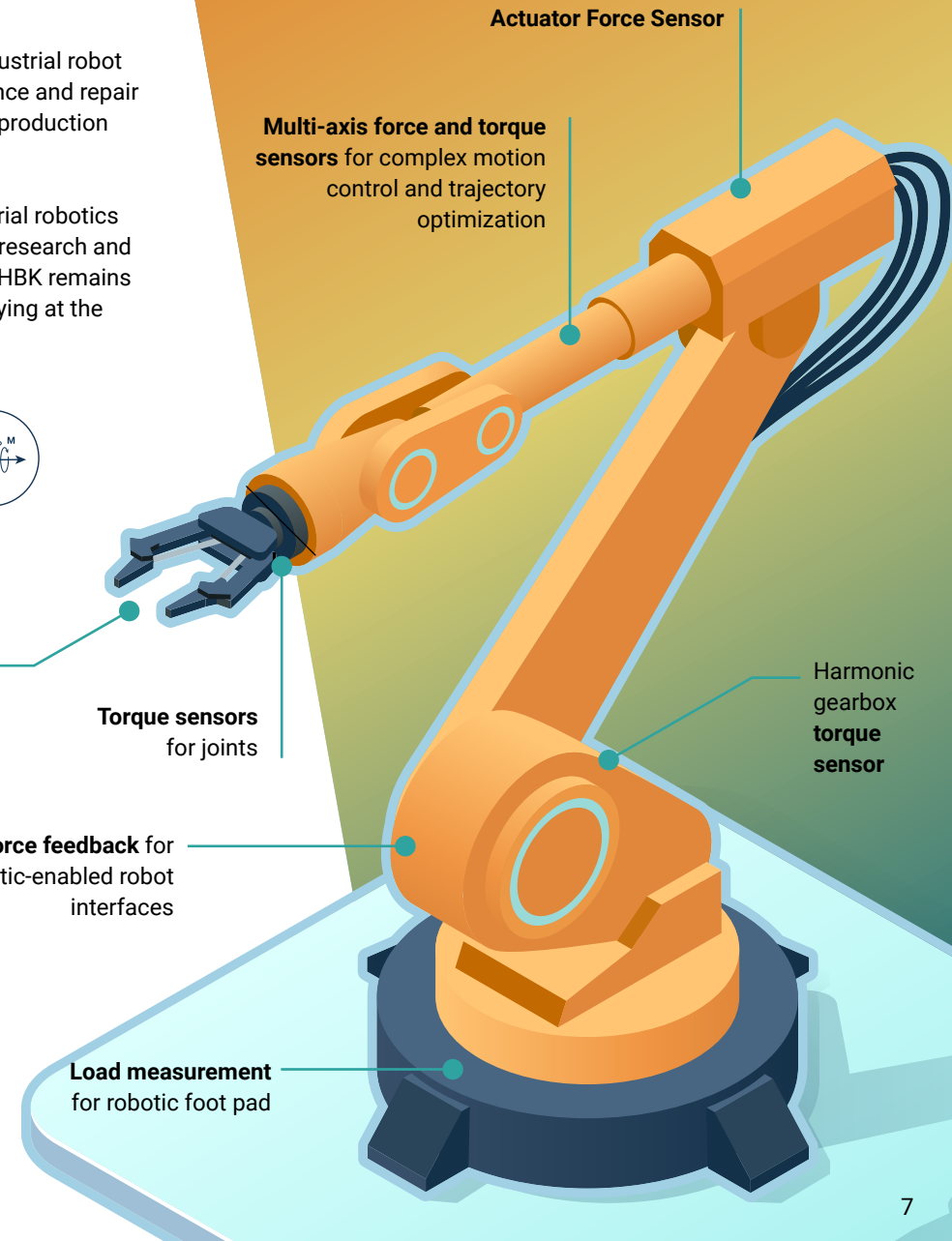
To tackle these challenges, modern industrial robots incorporate advanced sensor technologies that enable precise control and real-time feedback.

For instance, strain gauge sensors seamlessly integrate into tool and actuator housings, measuring torque and forces to ensure safety and continuous feedback. Six-degrees-of-freedom (6DOF) force and multi-axis sensors measure forces along three orthogonal axes – as well as moments or torques along these axes – ensuring precise handling and minimal applied force for each task.

HBK's sensor solutions offer industrial robot manufacturers exceptional precision, enhanced reliability, and improved control. By enabling more accurate and reliable

data collection, our sensors improve industrial robot performance and help reduce maintenance and repair needs – crucial elements in continuous production environments.

Well positioned to address future industrial robotics challenges, HBK invests in cutting-edge research and development. In this ever-evolving field, HBK remains committed to driving innovation and staying at the forefront of the industry.



Collaborative robots

While sharing some similarities with traditional industrial robots in material handling processes, collaborative robots or “cobots” are distinguished by their compact size and advanced technology.

These traits enable cobots to perform tasks like small parts assembly and machine tending – operations that are repetitive and potentially hazardous when done manually.

Types of cobots include collaborative robotic arms, mobile robots, exoskeletons, tabletop robots, handling robots, safety robots, and medical care robots.

Cobot designers face several challenges in meeting the requirements for precision, predictability, dexterity, stability, simultaneous control of multiple instruments, and the ability to operate in difficult-to-access conditions.

Crucially, the need for safe and effective human-cobot collaboration in industrial environments poses significant sensor design challenges, including:

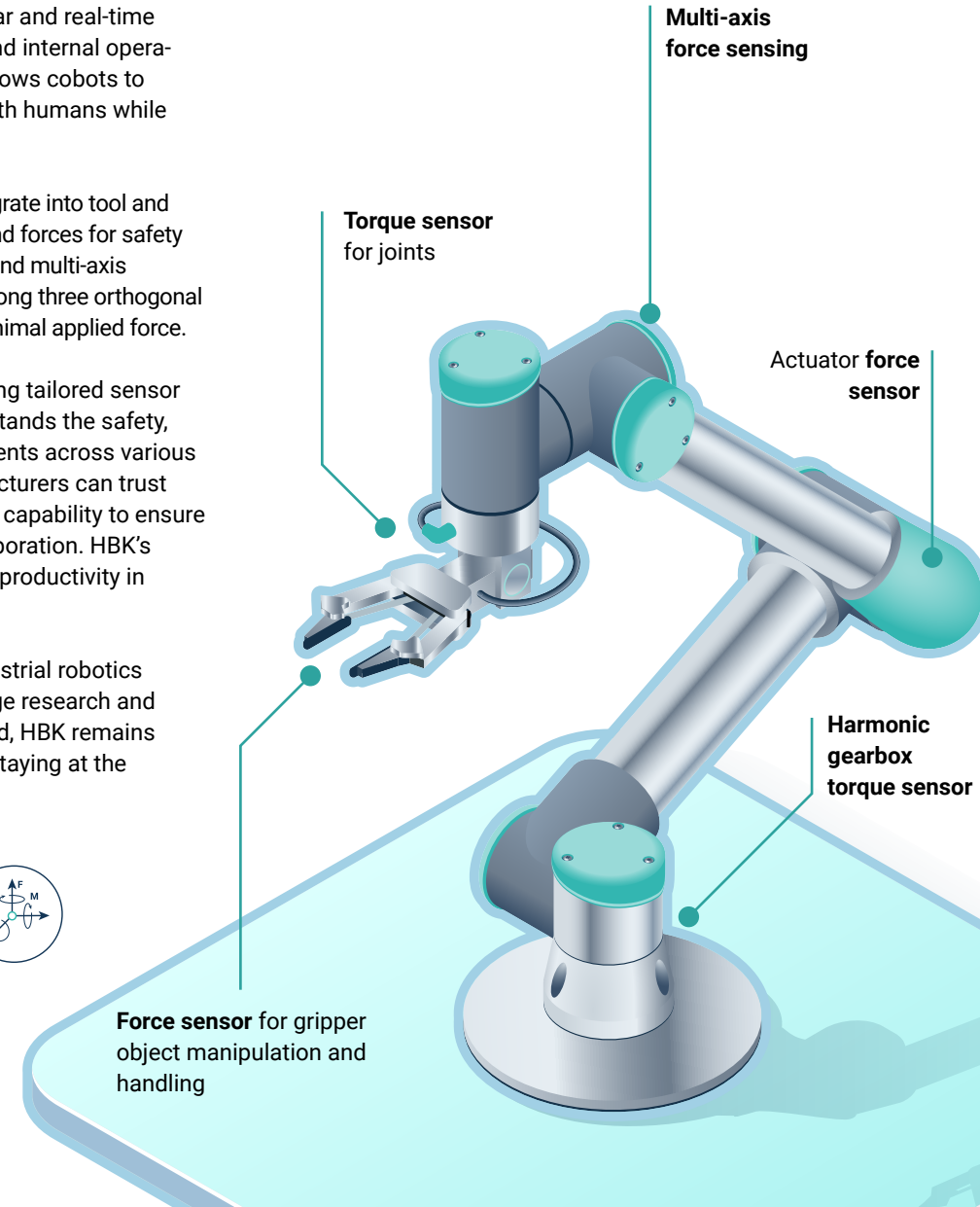
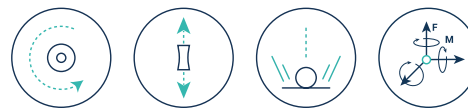
- Ensuring safety by detecting humans and objects
- Maintaining reliability despite environmental factors
- Effective integration
- Data accuracy and reliability
- Seamless integration with control systems
- Effective cost management
- Providing flexibility for diverse applications
- Handling large volumes of data
- Ensuring durability in harsh environments
- Addressing maintenance needs

It is essential for cobots to have a clear and real-time understanding of their environment and internal operations. Sensors collect the data that allows cobots to collaborate safely and productively with humans while minimising injury risk.

For example, strain gauge sensors integrate into tool and actuator housings, measuring torque and forces for safety and continuous feedback. 6DOF force and multi-axis sensors measure forces and torques along three orthogonal axes, ensuring precise handling and minimal applied force.

With extensive experience in developing tailored sensor solutions for cobots, HBK fully understands the safety, efficiency, and performance requirements across various industrial applications. Cobot manufacturers can trust HBK's sensor precision, reliability, and capability to ensure safe and effective human-cobot collaboration. HBK's solutions also contribute to improved productivity in cobot work environments.

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Medical robots

Medical robots have transformed surgical procedures over several decades. Robot-assisted surgery enables surgeons to perform complex procedures with greater precision and control, often through tiny, precise incisions for minimally invasive surgeries, though surgical robots can also assist in open surgeries.

Types of medical robots include teleoperated surgical robots, autonomous surgical robots, medical imaging robots, surgical assistance robots, and diagnostic/screening robots.

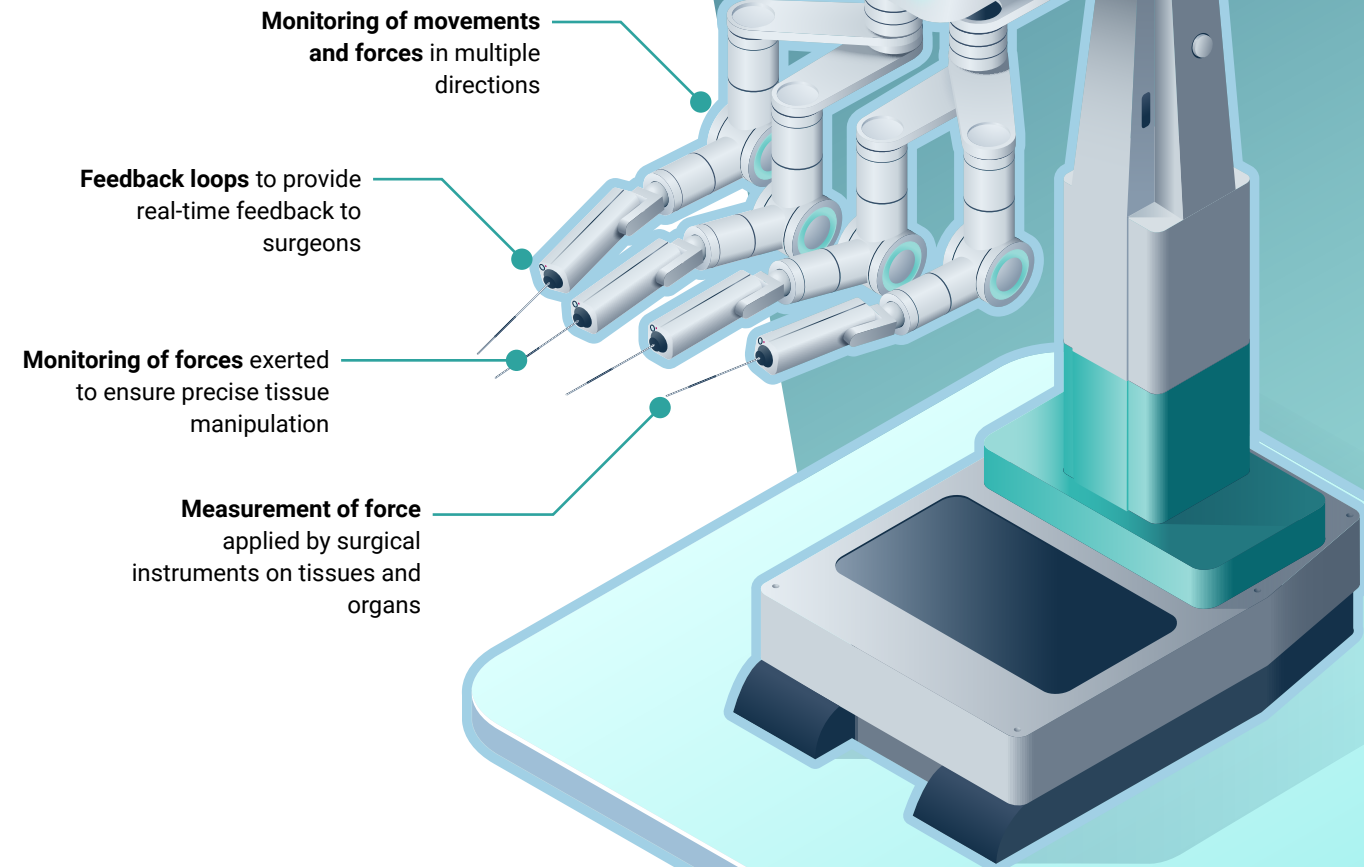
The medical/surgical robotics field presents numerous unique design challenges. Delicate procedures require extreme robot precision, and the patient's welfare is paramount throughout use. Ensuring wellbeing poses significant sensor design challenges, including:

- Accuracy and precision
- Miniaturisation
- Effective integration
- Data accuracy and reliability

To address these challenges, medical robots incorporate advanced sensor technologies for precise control and real-time feedback.

HBK pioneers tailored sensor solutions, ensuring superior performance and safety. Our force and torque sensors prevent tissue damage by providing feedback on applied forces. Miniaturised sensors from HBK enable operation in the confined spaces typical of minimally invasive surgery.

HBK sensors enhance robots' capabilities, allowing them to learn from surgical data to continuously improve performance. With real-time data analytics integration, HBK supports better decision-making and cutting-edge sensor technology that revolutionises medical robotics.



Agricultural robots

Modern agriculture faces significant challenges like meeting rising food demands amid labour shortages. An increasing number of farmers embrace automation and robotics to streamline processes. As a result, more and more food producers are deploying agricultural robots with diverse functionalities, including harvesting, weeding, spraying, monitoring/inspection, planting, pruning/trimming, and greenhouse harvesting robots.

These robotic systems use sophisticated sensors to collect actionable data from various sources, complemented by precise GPS coordinates and real-time climate/weather updates. This information convergence empowers autonomous operation by providing actionable insights.

Through meticulous data analysis and insight application, robots can adeptly adjust to environmental nuances and utilise resources efficiently. Combining analytical power with outcome metrics like yields and crop quality, while considering market dynamics, enables farmers to enhance operational efficacy and productivity.

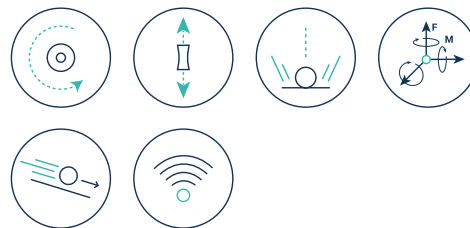
Submarkets including agricultural, mobile, and collaborative robots are all turning to robotics, fostering groundbreaking innovations. However, sensor integration presents multifaceted challenges including productivity optimisation, autonomy enhancement, sustainability, navigation precision, localisation accuracy, and operation in challenging terrains.

In response, HBK pioneers tailored sensor solutions, leveraging decades of expertise in the agricultural domain. HBK sensors enable crop health monitoring, assessment of agricultural machinery loads, irrigation

optimisation, navigation enhancement, terrain compensation and localisation refinement.

Our agricultural robot sensor solutions provide manufacturers with the means to enhance operational efficiency, reduce costs, and maximise yields. Leveraging cutting-edge technologies like strain gauges and inertial sensors, we foster innovation and competitiveness in agricultural robotics.

In addition, we closely collaborate with engineering teams to engineer tailored solutions that amplify productivity and fortify sustainability standards.



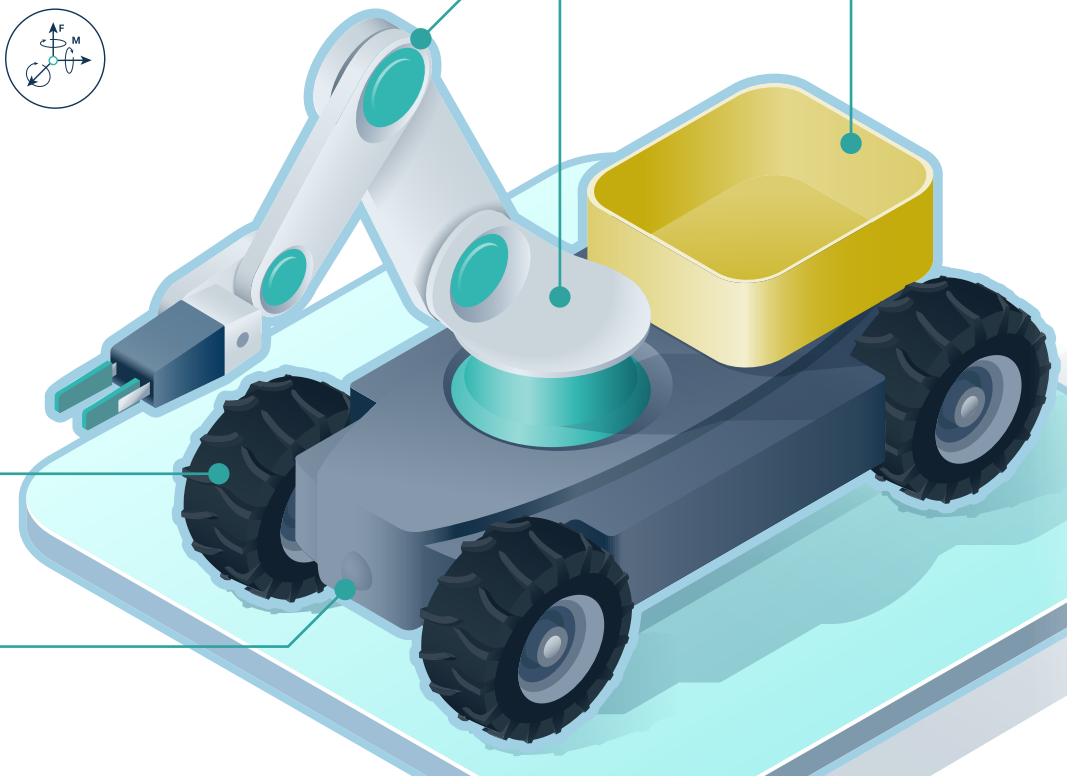
Controlling the speed and direction of rotation of various components of the robot, such as wheels

Inertial sensors to detect movement, make trajectory corrections, and maintain balance on uneven terrain

Force and load measurement for plowing, planting, object manipulation and handling

Rotational force or torque applied by motors or actuators in the robotic system

Inertial sensors to Measure linear and angular acceleration of the robot



Mobile robots

In today's industrial landscape, the complexities surrounding material handling and logistics have driven a growing interest in automated solutions like automated guided vehicles (AGVs), autonomous mobile robots (AMRs), and autonomous mobile manipulation robots (AMMRs).

These robotic systems offer unparalleled adaptability, playing pivotal roles across sectors such as logistics and warehousing. Beyond efficient goods transportation, they excel in executing intricate tasks like autonomous loading and unloading. Their utility spans industries from health-care to agriculture and transportation, streamlining inventory management, material conveyance, and even surface cleaning.

To cater to the nuanced needs of distinct environments, logistics managers deploy a diverse array of mobile robot types, including wheeled robots, tracked variants, bipeds, aerial robots, underwater models, quadrupeds, and modular iterations. Each offers unique advantages, depending on environmental factors and operational requirements.

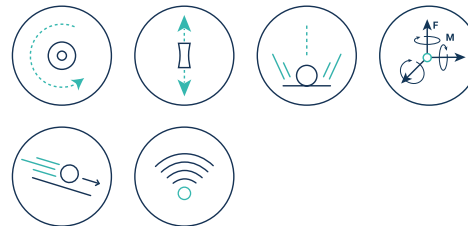
However, designing and implementing effective mobile robots presents formidable technical challenges. Beyond the need for precise navigation within dynamic, unstructured settings, the integration of reliable sensor arrays is crucial for ensuring robustness, safety compliance, terrain adaptability, precise weight assessment and handling, overload protection, seamless system integration, and enduring durability.

To meet the growing demands of this landscape, HBK offers a comprehensive suite of tilt, load, and multi-axis

measurement sensors expressly tailored for mobile robotic applications. Our wireless solutions confer heightened flexibility, enabling real-time data acquisition and seamless communication with robotic systems.

HBK also provides IMUs and complete inertial navigation systems, adeptly addressing localisation and navigation requirements within complex and evolving environments.

By combining our technological expertise with an astute comprehension of the challenges faced by our clients in mobile robotics, we are committed to providing innovative solutions that optimise operational efficiency, fortify reliability, and bolster safety protocols within industrial contexts.

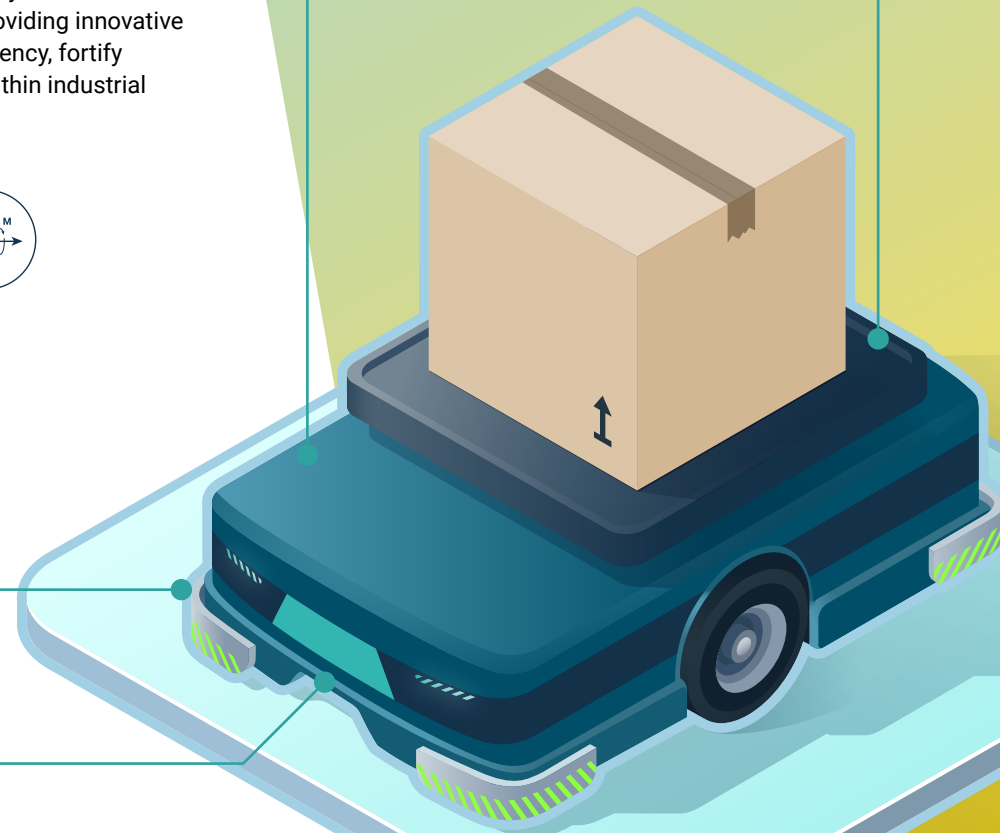


Inertial sensors estimate position and orientation, and maintain a stable trajectory despite external disturbances

Inertial sensors: Utility:
Measure linear and angular acceleration of the robot to detect motion

Measure the load supported by the robot to monitor payload, ensure balanced weight distribution, and prevent overloads

Tilt sensors: Measure angle of the robot to navigate inclined terrain, prevent tipping, and ensure stable and safe operation



KEY CONSIDERATIONS

Choosing the right robotic sensor solution

When it comes to choosing sensors for robotic systems, several crucial factors demand attention. From selecting the right sensor type tailored to your specific application needs, to rigorously evaluating accuracy, resolution, and response time—every detail is pivotal for achieving optimal performance.

This guide unpacks essential considerations to empower you to make informed decisions and maximize the efficiency of your robotic systems.

Optimizing Robotic Sensor Selection

- **Type of sensor:** Determine the specific type of sensor needed based on the application requirements.
- **Accuracy and precision:** Evaluate the accuracy and precision of the sensor to ensure it meets the necessary performance standards for your robotic system.
- **Resolution:** Assess the sensor's resolution, which determines its ability to detect fine details or small objects within its detection range.
- **Response time:** Evaluate the response time of the sensor to ensure it can provide real-time data for controlling the robotic system effectively.
- **Environmental conditions:** Consider the environmental conditions in which the sensor will operate, such as temperature, humidity, dust, and vibration levels, to ensure the sensor is suitable for the application's operating environment.
- **Integration and compatibility:** Ensure that the sensor can be easily integrated with the robotic system's hardware and software platforms. Check for compatibility with communication protocols
- **Power consumption:** Evaluate the sensor's power consumption to ensure it aligns with the energy requirements and constraints of the robotic system.
- **Reliability and durability:** Assess the reliability and durability of the sensor, allowing for continuous operation and preventing potential wear and tear in industrial or harsh environments.
- **Cost and budget:** Consider the cost of the sensor solution and how it fits within the project budget, taking into account not only the upfront costs but also maintenance and replacement expenses.
- **Scalability and future upgrades:** Determine if the sensor solution allows for scalability and future upgrades to accommodate evolving requirements or new functionalities in the robotic system.

The robotic sensors of tomorrow

Emerging trends in robotics offer an exciting insight into recent developments. For instance, one major breakthrough is the increasing integration of artificial intelligence (AI) and machine learning into industrial robots. These new technologies improve the adaptability and efficiency of robots, allowing them to learn and adapt to complex and variable tasks.

Advanced sensors and computer vision have had profound impacts on collaborative robots, enabling them to work safely and efficiently alongside humans in dynamic environments, including flexible production lines and automated warehouses.

These technologies also have societal and futuristic impacts. In the agriculture industry, automation represents a promising way to promote more sustainable and efficient food production, potentially contributing to solving global challenges linked to food security and resource use.

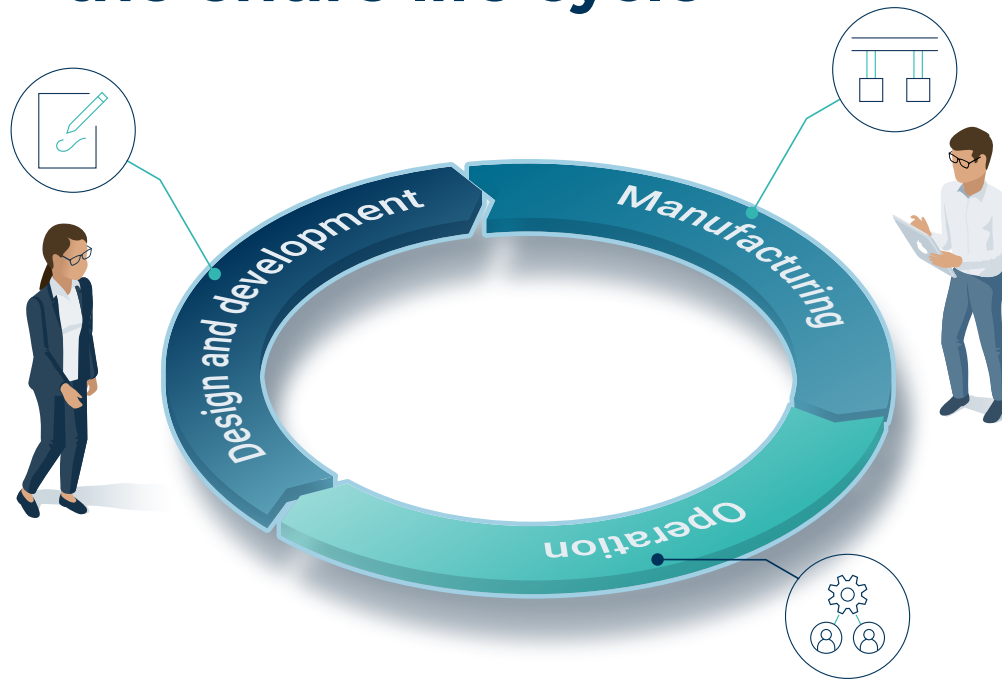
There are also many emerging synergies between different robotics submarkets, with technologies developed for mobile cobots presenting new opportunities for agricultural robots. For example, advances in autonomous navigation and sensory perception can be applied to improve the precision and safety of agricultural robots in variable outdoor environments.

The robots of tomorrow will be profoundly influenced by advances in sensor technologies. These devices play a crucial role in enabling robots to interact with their environment in a more intelligent and adaptable way, opening up new frontiers of innovation in all areas of robotics.

The use of robots and robotics has rapidly spread into multiple industries, with the robotics technology industry estimated to be worth US\$283 billion by 2032.



Your sensor technology partner through the entire life cycle



Design and development

HBK's team of experienced engineers provide customised solutions tailored to your specific needs, enabling optimisation across sensors, electronics, and connections. These solutions are instrumental in measuring torque, mass, pressure, and more, particularly when standard sensors fall short. Seamlessly integrating data ensures flawless control functions. By collaborating with HBK's OEM sensor experts, you can enhance the safety, durability, and efficiency of your robots and cobots, leveraging both the expertise of your product engineers and HBK's specialised knowledge.

In laboratory environments, strain gauges, temperature sensors, and vibration sensors play crucial roles in conducting tests and analyses for fatigue, stress, durability, and other parameters. These sensors deliver reliable and reproducible measurements, vital for scientific experiments and quality control checks.

HBK also offers comprehensive testing and analysis solutions that complement simulation and physical testing, supporting designers throughout the sensor development process and the transformation of components into active sensors.

Manufacturing

HBK provides sensor, electronic, and wiring solutions adhering to rigorous quality standards, catering to manufacturers' need for enhanced profitability and customer satisfaction while ensuring safety in robot design through data collection and analysis.

With manufacturing capabilities across the USA, EU, and Asia, HBK delivers scalable sensor volumes and integrated industrial process control solutions, meeting customer demands for flexibility, adaptability, and high precision in ongoing production processes.

Operation

HBK offers a wide range of reliable and customisable sensor technologies, ensuring optimal performance and safety for robot operators across various applications.

Moreover, our asset condition monitoring solutions allow for proactive maintenance planning, cost optimisation, and enhanced safety by detecting signs of wear or damage in mechanical parameters over time.

We deliver precise and durable sensors through advanced technology and rigorous testing, providing reliable solutions for the most demanding applications.



Cecelia Zhen

CUSTOM SENSOR ENGINEER, 6 YEARS AT HBK

After earning a master's degree in Mechanical engineering from Northeastern, Cecelia Zhen joined HBK as an OEM Custom Sensor Engineer, specializing in advanced load sensor architectures. She later earned a certification in Applied Data Science from MIT through HBK's reimbursement program.

Contact us

Ready to take the next step? Get in touch with the HBK team for a personalised consultation to assist with your robotic sensor needs.



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